Forecasting Livestock Prices: Fixed and Stochastic Coefficients Estimation Comparisons*

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Agricultural commodity analysts have systematically overpredicted livestock prices during the 1980s by using econometric forecasting models that do not account for changing economic conditions. This article compares the out-of-sample forecast performance of the Swamy–Tinsley stochastic coefficients model with ordinary least squares, Cochrane–Orcutt, and maximum likelihood procedures that estimate red meat and chicken prices. The ability of a stochastic coefficients model to adapt quickly to changing economic conditions helps make it almost uniformly superior to a fixed coefficients model in forecasting the quarterly retail price for beef and chicken. The Cochrane–Orcutt and maximum-likelihood procedures appear to forecast pork prices better.

INTRODUCTION

Recent overprediction of livestock prices has led many experts to believe that the structure of both demand and supply in the meat industry has changed over this

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decade. The hypothesized structural change on the demand side is said to be due to consumers' growing awareness of the relationship between fat, cholesterol, and good health. On the supply side, the Soviet grain deal, worldwide weather problems, the introduction of flexible exchange rates, the implementation and removal of price controls, and two oil price shocks were perceived as initiating shifts in livestock production technologies. Recent research addressing this issue includes Eales and Unneveher,[1] Chalfant and Alston,[2] Moschini and Mielke,[3] and Wohlgenant.[4]

We examine the value of stochastic coefficients models in providing better forecasts than fixed coefficients models because of nonstationary disturbances that may or may not be related to structural change. To compare forecasts, we re-estimate the meat demand equations from a quarterly model[5] to detect the extent of parameter variation, whether any systematic pattern in parameter variation is discernable, and whether or not out-of-sample forecasting can be enhanced. USDA currently uses this model for both policy analysis and forecasting simulation. In the spirit of Boland,[6] we believe it is always prudent for researchers to use a formal instrumentalist argument and vigorously seek more robust forecasting alternatives to standard fixed coefficients models.

A STOCHASTIC COEFFICIENTS EMPIRICAL MODEL

A first-order variant of the generalized autoregressive integrated moving average (ARIMA) stochastic coefficients process model, developed by Swamy and Tinsley,[7] was used to estimate the livestock demand equations for beef, pork, and chicken. Their model represents a generalization of several other fixed and stochastic coefficients models (see Swamy, Conway, and LeBlanc[8]). Several successful empirical applications of this model have appeared in the recent 'macroeconomic literature. See for example, Resler et al.,[9] Swamy, von zur Muehlen, and Farr,[10] Swamy and Tinsley,[7] Swamy, Tinsley, and Moore,[11] and Tinsley et al.[12]

Each coefficient in Swamy and Tinsley's model may vary about its own mean value by an error term which is assumed to be related to its own past value as well as the previous past values of the error terms in other coefficients. The error term is assumed to contain a white-noise component which is contemporaneously correlated with the white-noise components of the error term in other coefficients. See Swamy and Tinsley[7] for a more technical discussion of this model.

Both the conditional expected value and variance of the dependent variable may vary with observations on the conditioning variables. One may decompose the variance in the dependent variables among its contributing factors (see Swamy and Tinsley, p. 135).[7] It is important to allow the independent variable to influence the variance of the dependent variable. An independent variable may have a relatively large effect on the variance of the dependent variable even though it has a relatively minor effect on the mean of the dependent variable. The decomposition Swamy and Tinsley propose is analogous to allocation of the multiple R^2 among the explanatory variables in a conventional regression equation, Theil.[13]

EMPIRICAL RESULTS

We use the livestock price-dependent demand equations taken from the quarterly livestock model developed by Stillman.[5] The theoretical foundation for the price-

dependent demand form is provided by Wold.[14] The empirical fixed coefficients specification for the livestock demand relations with anticipated signs for each variable are as follows:

$$P_{it} = \beta_{oi} + \beta_{1i} BC_t + \beta_{2i} PC_t + \beta_{3i} CC_t + \beta_{4i} PCE_t + e_t, \qquad (1)$$

where i represents beef, pork, or chicken equations; P_i represents real retail meat price for commodity i; BC represents beef per capita consumption; PC represents pork per capita consumption; CC represents chicken per capita consumption; PCE represents real per capital total consumption expenditures; and e represents an error term.

Data sources for the price model are generated by USDA's Economic Research Service from USDA's National Agricultural Statistics Service and from the Bureau of Economic Analysis of the Department of Commerce. The per capita consumption data are closely related to a domestic disappearance concept. Production is known, so other uses are subtracted from this data and the residual is domestic disappearance. The other use numbers are small compared with the domestic disappearance data. Therefore, the errors in the other use data should be small compared with the disappearance numbers. The price series for these meats are a composite of Bureau of Labor Statistics' (BLS) cut prices. The quarterly weights of each cut for beef and pork are fixed and do not vary as the slaughter mix changes. For example, increasing cow slaughter and increasing the supply of hamburger do not change the weight of hamburger in the composite price series. In contrast, the price of chicken is reported as a whole-bird price. The whole bird has been replaced in recent years with cut-up birds and packages of specific parts. These composite and whole-bird prices do not reflect the actual mix of the product that reaches the consumer. The stochastic coefficients model desribed below may account for some of these data discrepancies.

The authors re-estimated livestock demand equations specified by Stillman during the 1964I–1979IV (the Roman numerals represent quarters) timespan. The data are not seasonally adjusted. The stochastic coefficients method yields a mean parameter value for each time period. However, time-varying coefficients are flexible enough to capture the effect of seasonal patterns within the coefficients themselves.

We allow the coefficients of the demand functions to change over time. We assume that tastes change over time and are different for different individuals. Because individuals are viewed to have different tastes, community utility functions may not exist. Consequently, our results are not subjected to the restrictions that maximization of a community utility function would imply. Goldberger[15] in his monograph on demand theory also acknowledges that some choice must be made as to which coefficients should be held fixed.

If the use of restrictions results in efficiency gains, then it is desirable to estimate the complete set of demand functions imposing those restrictions. On an empirical level, it has been shown by Revankar[16] and Mehta and Swamy[17] that joint estimation of a complete set of demand functions does not always lead to more efficient estimates than equation by equation estimation.

Estimates of the stochastic coefficients are determined by iterative procedure. The authors applied 10 iterations of the Swamy and Tinsley procedure. Because maximum likelihood estimates of the model may not exist we do not iterate on Swamy and Tinsley's method for convergence since it is not guaranteed to converge. To avoid overfitting, we choose estimates which minimize the root mean

square forecast error. The root mean square forecast error is generally a good
substitute for an averaged within-sample residual sum of squares. This issue is
discussed in Swamy, Conway, and LeBlanc.[8,18] The specific stochastic coeffi-
cients equations are as follows:

$$P_{it} = \beta_{oit} + \beta_{1it}\, BC_t + \beta_{2it}\, PC_t + \beta_{3it} CC_t + \beta_{4it} PCE_t, \qquad (2)$$

where i represents beef, pork, or chicken equations. Each of the coefficients of
these linear regressions are driven about a fixed vector of mean values, by a
stationary stochastic vector.

Tables I through III compare estimated fixed coefficients results with
stochastic coefficients (S–C) mean values of the beef, pork, and chicken price-
dependent demand relations. Fixed coefficients models chosen for comparison
were ordinary least squares (OLS) models estimated by Cochrane–Orcutt (C–O)
and maximum-likelihood (M–L), respectively, under the assumption of first order
auto-correlation, and the OLS model with ARIMA-fitted residuals. There are
significant differences in coefficients magnitudes of the fixed and stochastic
coefficients models for all commodities.

Tables I through III also show the coefficients of variation of coefficients in
brackets. The coefficients of variation of coefficients indicate the extent to which
the coefficients are stable. For the beef equation, the intercept (omitted vari-
ables) has the most volatile coefficients, followed by chicken per capita con-
sumption, pork per capita consumption, real personal consumption expendi-
tures, and beef per capita consumption. For the pork equation, a similar ranking
follows with the intercept (omitted variables) having the most volatile coeffi-
cients, followed by chicken per capita consumption, beef per capita consump-
tion, and pork per capita consumption. This table shows that the own per capita
consumption parameter for all commodities tends to be ranked very low (last for
beef and pork and second to last for chicken). On the other hand, real personal
consumption expenditures appear to be relatively stable for beef and pork and
volatile for chicken. Our empirical model contains only the close substitutes
among the meat groups in the consumers' demand relationship. The variability in
the intercept term and the other product consumption numbers, compared with
the relative stability of the own quantity and expenditure parameters, may sug-
gest that the stochastic coefficients model is capturing some of the influence of
the omitted variables in the consumer demand relationship. The instability of the
real expenditure coefficients for chicken may reflect the relative declining price
of chicken in relation to the other meats, and the switching of consumer to
poultry as other costs or reductions in disposable income affected consumer
budgets.

As mentioned earlier, we can determine the proportion of the total average
variance of the dependent variable contributed by each independent variable.
Estimates of the average decomposition of the normalized variance (ADNV),
which sums to unity when the net contributions are added up, are shown in Table
IV for beef, pork, and chicken.

For real beef retail prices, the intercept (omitted variables) has the largest
influence, followed by pork per capita consumption, chicken per capita con-
sumption, beef per capita consumption, and real personal consumption expendi-
tures. For real pork retail price, real personal consumption expenditures have the
lion's share of influence, followed by pork per capita consumption, chicken per

Table I. Beef Price Equation Estimated Parameters.

Independent Variable		Estimation Procedures		
	Varying Parameter[1]	OLS	Cochrane–Orcutt	Maximum-Likelihood
		Timespan 1964I–1979IV		
Constant	169.53(5.8)[2] [198.295][5]	122.88(7.8)	160.75(7.7)	145.10(7.6)
Beef Consumption	−4.65(−5.2) [1.384]	−3.21(−4.7)	−2.67(−4.4)	−2.42(−4.0)
Pork Consumption	−.859(−.6) [39.4457]	−.727(−1.3)	−.830(−1.4)	−.827(−1.4)
Chicken Consumption	.737(.8) [55.495]	.935(1.2)	.664(.7)	.989(1.0)
Personal Expenditures	.174(1.5)[3] [1.397]	.261(3.1)	−.035(−.5)[3]	−.0085(−.1)
R^2	NA	.45	.33[4]	.59[4]
DW	NA	.607	2.15[4]	2.11[4]
RHO (initial)	NA	NA	.697	NA
RHO (final)	NA	NA	.891	.891

NA = Not applicable.
[1]Conditioned on iteration estimates of Φ and Δ_u.
[2]Values in parentheses, except those marked by footnote [3], represent t-statistics.
[3]Values in parentheses represent asymptotic t-statistics.
[4]Based on rho-transformed variables.
[5]Values in brackets represent estimated coefficients of variation of coefficients.

Table II. Pork Price Equation Estimated Parameters.

Independent Variable	Estimation Procedures			
	Varying Parameter[1]	OLS	Cochrane–Orcutt	Maximum-likelihood
	Timespan 1964I–1979IV			
Constant	130.99(73.9) [1.128]	126.37(9.9)	129.55(7.1)	116.24(7.1)
Beef Consumption	−.538(−8.5) [.248]	−.264(−.5)	.654(1.1)	.902(1.6)
Pork Consumption	−5.014(−92.6) [.0888]	−4.547(−10.3)	−4.042(−7.5)	−4.062(−7.5)
Chicken Consumption	−4.038(−38.1) [1.0579]	−3.064(−3.3)	−3.600(−2.4)	−3.276(−3.8)
Personal Expenditures	.423(44.6) [.0047]	.311(4.5)	.144(2.4)	.173(3.0)
R^2	NA	.70	.53	.63
DW	NA	.672	1.61	1.60
RHO (initial)	NA	NA	.660	.787
RHO (final)	NA	NA	.813	.787

NA = Not applicable.
[1]Conditioned on iteration estimates of Φ and Δ_u.

Table III. Chicken Price Equation Estimated Parameters.

	Estimation Procedures			
Independent Variable	Varying Parameter[1]	OLS	Cochrane–Orcutt	Maximum-Likelihood
		Timespan 1964I–1979IV		
Constant	95.89(8.3) [113.746]	97.00(13.3)	96.10(9.5)	94.88(10.1)
Beef Consumption	−.953(−2.4) [18.062]	−1.042(−3.3)	−.795(−2.2)	−.765(−2.2)
Pork Consumption	−1.317(−4.3) [2.3915]	−1.704(−6.6)	−1.907(−5.8)	−1.910(−5.8)
Chicken Consumption	−2.084(−3.0) [16.417]	−2.034(−3.8)	−1.691(−3.2)	−1.663(−3.2)
Personal Expenditures	.00025(0.6) [140.40]	.045(1.1)	.014(.4)	.016(.4)
R^2	NA	.63	.47	.67
DW	NA	.882	2.072	2.057
RHO (initial)	NA	NA	.557	NA
RHO (final)	NA	NA	.603	.599

NA = Not applicable.

[1]Conditioned on iteration estimates of Φ and Δ_u.

Table IV.   Average Decomposition of Normalized Retail Price Variance.

Independent Variable	Intercept	Beef Consumption	Pork Consumption	Chicken Consumption	Real Personal Consumption Expenditures
			Beef		
Intercept	55.617	12.241	−26.3	−17.7	19.9
Beef Consumption	12.241	4.784	−5.893	−4.236	−6.025
Pork Consumption	−26.3	−5.893	12.914	8.003	9.576
Chicken Consumption	−17.7	−4.236	8.003	6.167	6.542
Real Personal Consumption Expenditures	−19.9	−6.025	9.576	6.542	9.015
Net Contributions	3.958	.871	−1.7	−1.224	−.792
			Pork		
Intercept	0.00005	−0.0002	0.00015	0.001	−0.00137
Beef Consumption	−.0002	.0212	.0031	.0019	−.028
Pork Consumption	.00015	.0031	.0110	−.0013	.0202
Chicken Consumption	.001	.0019	−.0013	.0040	.0123
Real Personal Consumption Expenditures	−.00137	−.028	.0202	.0123	.951
Net Contributions	−.00037	−.002	.03315	.0179	.954
			Chicken		
Intercept	107.73	−88.86	−30.58	−22.88	38.81
Beef Consumption	−88.86	76.875	26.181	23.254	−41.439
Pork Consumption	−30.58	26.181	10.765	12.603	−20.129
Chicken Consumption	−22.88	23.254	12.603	26.685	−40.892
Real Personal Consumption Expenditures	−38.81	41.439	−20.129	−40.892	66.814
Net Contributions	4.22	−3.989	−1.16	−1.23	3.164

capita consumption, beef per capita consumption, and the intercept (omitted variables). Finally, for real chicken retail price, the intercept (omitted variables) has the greatest influence, followed closely by beef per capita consumption and real personal per capita consumption expenditures. Chicken per capita consumption and pork per capita consumption complete the relative ranking.

Figures 1 and 2 show the timepath of the own quantity coefficients and corresponding flexibilities of the beef retail price equation. The movements of the coefficients appear to coincide with some historical events in the livestock industry. The 1960s to the mid-1970s was a period of growth in beef consumption. During this period expansion in the cattle sector was spurred by increased beef
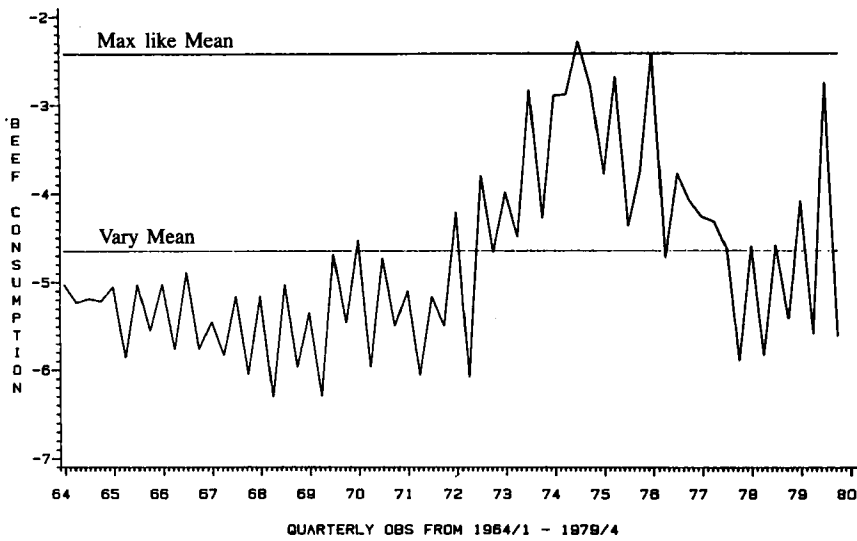
Figure 1. Plot of Varying Parameters: Beef Price Equation. Independent Variable: Beef Consumption, Estimation Period: 64/1–79/4.

expenditures as a percentage of income and a rapid rise in the cattle inventory. The model reflects this increase in demand by smaller price response flexibilities. Also, beef consumption rose from about 82 to 86 pounds per capita. The cattle sector grew rapidly and started to pull cropland into cattle production. Around 1975, bad weather and high grain prices caused the cattle industry to
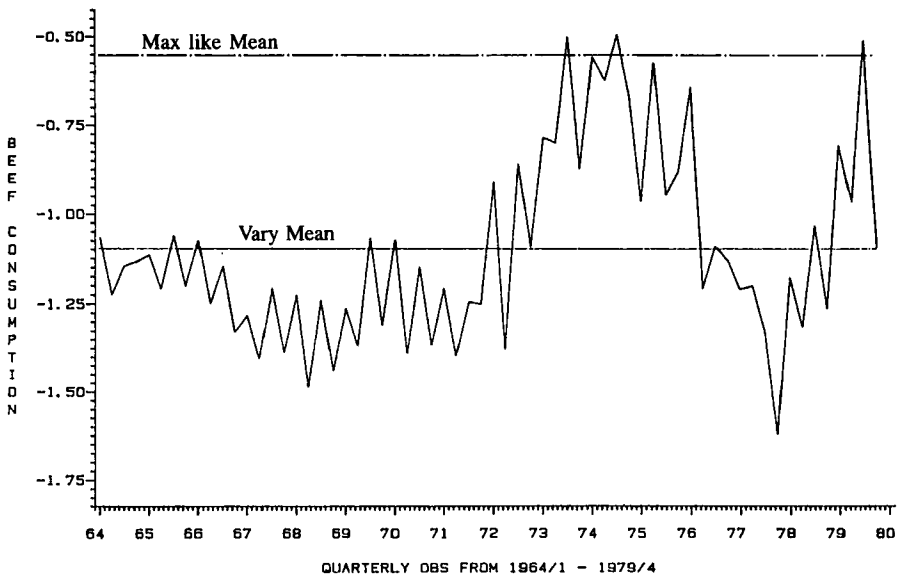

Figure 2. Plot of Flexibilities: Beef Price Equation. Independent Variable: Beef Consumption. Estimation Period: 64/1–79/4.
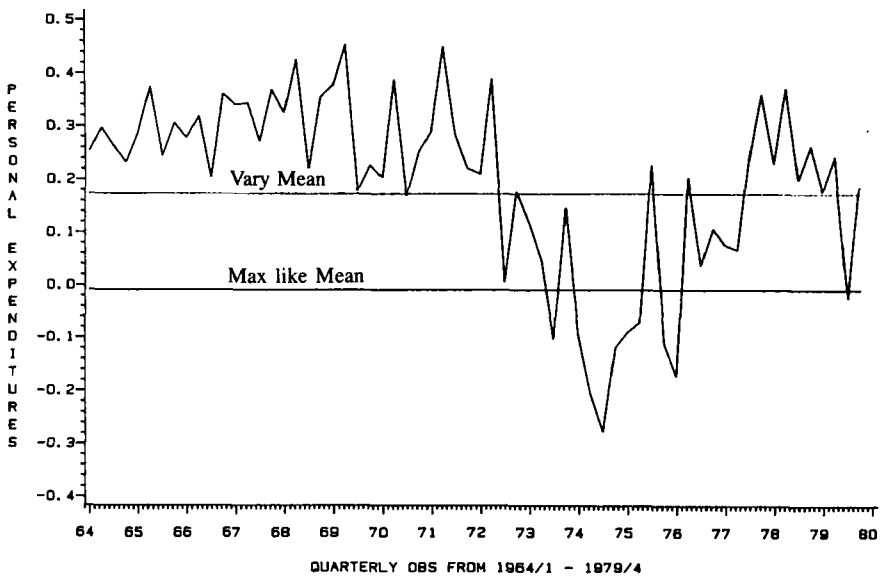
Figure 3. Plot of Varying Parameters: Beef Price Equation. Independent Variable: Personal Expenditures. Estimation Period: 64/1–79/4.

liquidate its herds. Beef supplies jumped rapidly by record amounts from 1976–78. This increase seemingly induced a threshold level of beef consumption, and is reflected in the model by the rapid decline in the coefficients.

The time profile for the coefficients and flexibilities in real per capita expenditures (RPCE) for beef also reveal an interesting pattern. (See Figs. 3 and 4). After
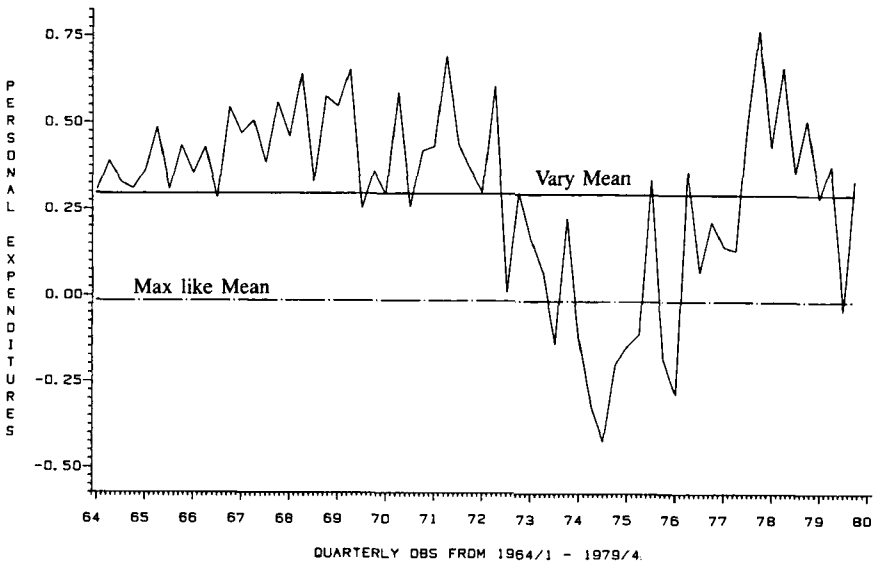
Figure 4. Plot of Flexibilities: Beef Price Equation. Independent Variable: Personal Expenditures. Estimation Period: 64/1–79/4.

exhibiting relative stability form 1964–71, the coefficients decrease (and actu-
ally turn negative), rebound, and decrease again. The coefficients and flex-
ibilities appear to follow a business cycle pattern (as defined by the National
Bureau of Economic Research). The general economy experienced a deep reces-
sion from 1973IV through 1975II, an extremely vigorous recovery from 1975III
through 1978IV, then weakened again in 1979. In contrast, the general economy
exhibited fairly steady growth during the 1960s, followed by only a brief mild
recession in 1970, periods when the consumer demand coefficients were rela-
tively stable. Periods of economic stability seem to imply a fairly constant influ-
ence of changes in real per capita expenditures on changes in beef prices, while
periods of economic volatility seem to imply similar volatility for this coefficient.

Of course, the economy sustained a number of exogenous shocks during the
1970s, including the imposition and removal of price controls, two major oil
price shocks, and dramatic changes in monetary policy. The time profile is likely
picking up some effect of these events, even without specifying them (recall that
the varying parameter technique absorbs the effect of omitted variables). Similar
breakdowns of standard relationships have also been observed and cited in the
macroeconomic literature.[11,19] The contribution of this varying parameter tech-
nique is that it seems to actually learn from the historical data (absorbing these
shocks into the parameters) and provides almost uniformly superior out-of-sam-
ple forecasts.

Figures 5 and 6 show movements in the own quantity coefficients and flex-
ibilities in pork, reflecting some beliefs about possible nonlinearities in pork
demand. Many analysts in the livestock industry have long felt that there is a
kinked or nonlinear demand for pork. Prices are related linearly to pork quantity
within the range of about 52–62 pounds per capita. Above this range, satiation
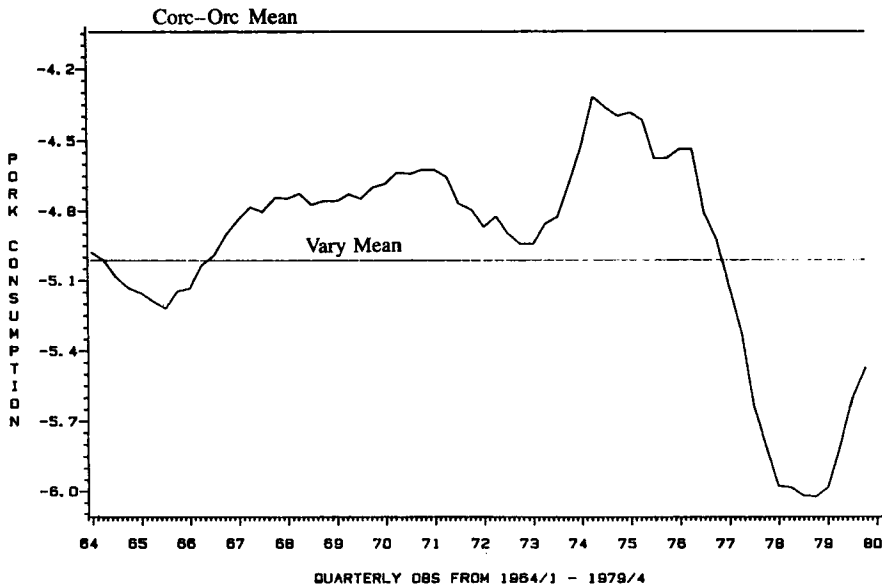occurs and demand becomes flexible. Below this range, demand becomes very

Figure 5. Plot of Varying Parameters: Pork Price Equation. Independent Variable:
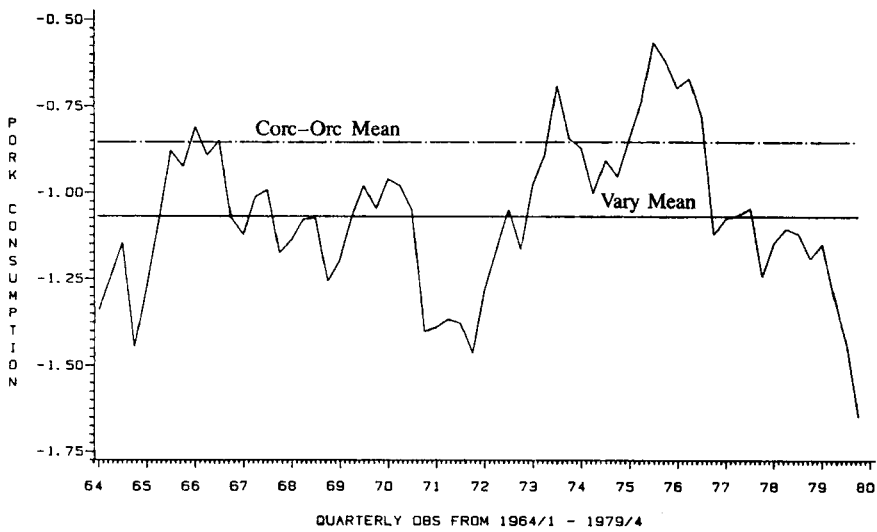Pork Consumption. Estimation Period: 64/1–79/4.

Figure 6. Plot of Flexibilities: Pork Price Equation. Independent Variable: Pork Consumption. Estimation Period: 64/1–79/4.

inflexible. In examining the time plot of the pork own quantity parameters and flexibilities, 1970–72 and 1976–80 were periods of consumption exceeding those satiation levels and 1974–75 were below those levels. As postulated, the pork own quantity flexibility becomes much more flexible as the quantities exceed the 62-pound limit and becomes less flexible as the quantities drop below 52 pounds.
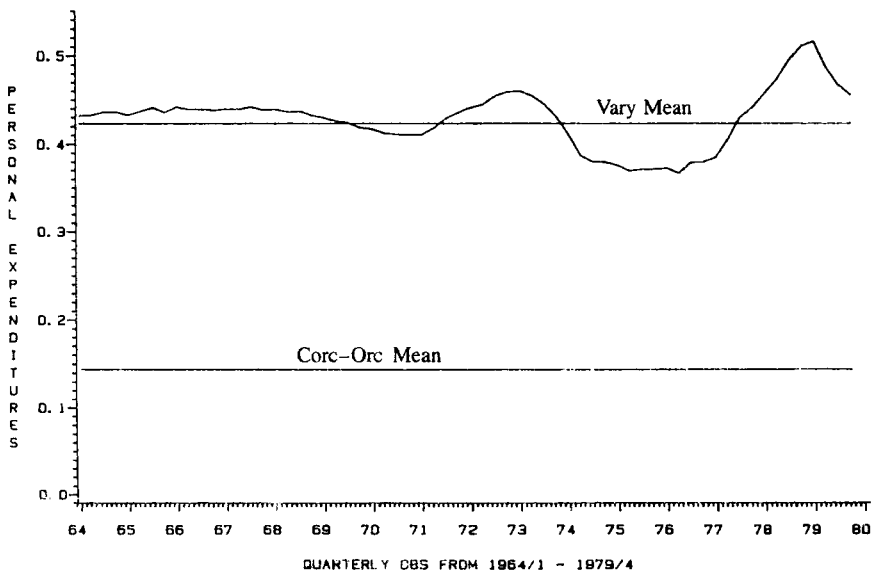

Figure 7. Plot of Varying Parameters: Pork Price Equation. Independent Variable: Personal Expenditures. Estimation Period: 64/1–79/4.
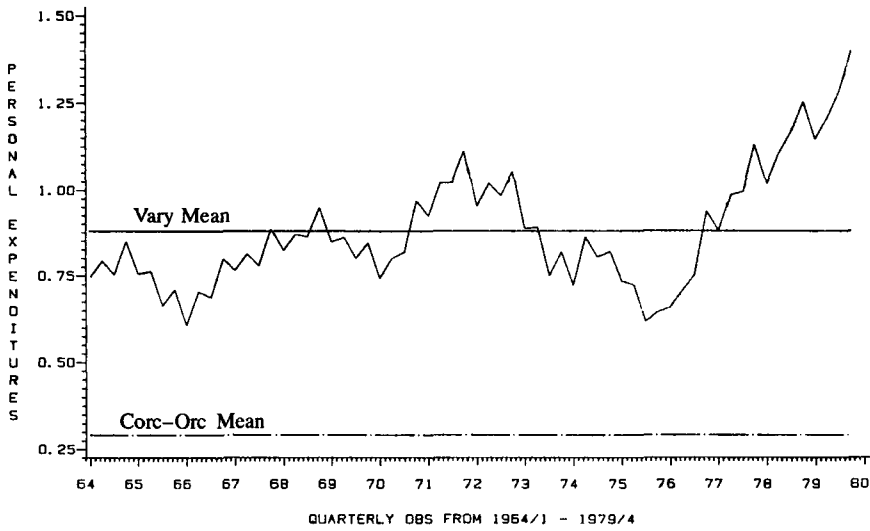
Figure 8. Plot of Flexibilities: Pork Price Equation. Independent Variable: Personal Expenditures. Estimation Period: 64/1-79/4.

An examination of the time profile of the coefficients and flexibilities in real per capita expenditures for pork, shown in Figures 7 and 8, reveal a pattern similar to beef real expenditures. These coefficients and flexibilities also appear to follow a business cycle pattern. However, the progress of the coefficients and flexibilities follow a smoother, less volatile pattern, and one unmarked by the negative relationship beef experienced in 1974-76.

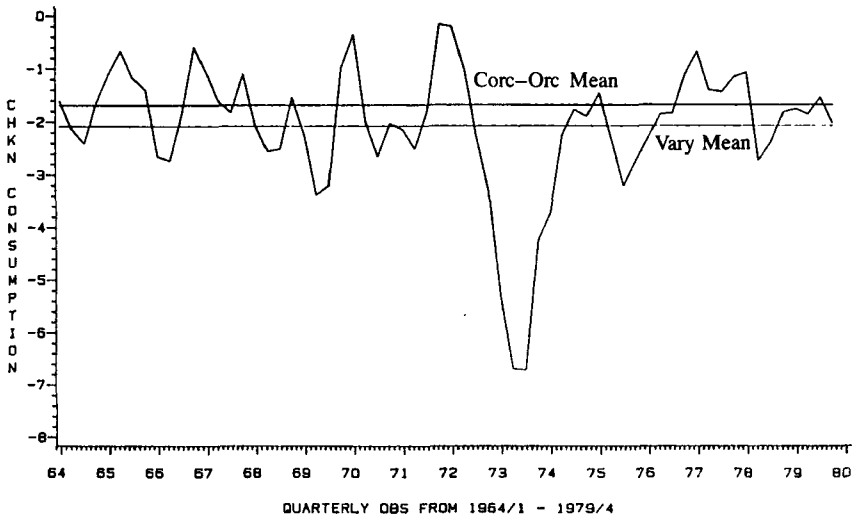Broiler consumption increased over the period examined in the model. One

Figure 9. Plot of Varying Parameters: Chicken Price Equation. Independent Variable: Chicken Consumption. Estimation Period: 64/1-79/4.
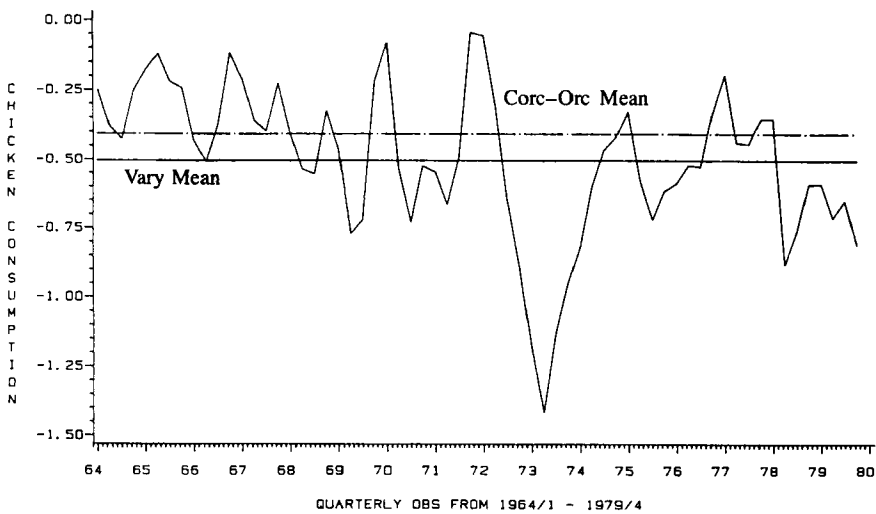
Figure 10. Plot of Flexibilities: Chicken Price Equation. Independent Variable: Chicken Consumption. Estimation Period: 64/1–79/4.

reason for this trend was that technological advance allowed broiler producers to offer a larger supply and a declining real price. However, an examination of the parameters shows no systematic pattern over the estimated time period reflecting this event. The own quantity parameters and flexibilities for broilers, shown in Figures 9 and 10, remain centered around the mean value with the exception of the period between 1972–73. During this period, the Nixon administration implemented a wage price freeze, and real grain prices were extremely high. The broiler industry reacted by reducing production. Also, the market was subject to an element of uncertainty since wholesale prices for broilers were not quoted for several months. Finally, responsibility for constructing the index shifted from USDA to BLS; and, as result, in 1978 the data methodology for chicken retail price was changed. There is a downward shift at this point in the timeplot of both the parameters and flexibilities. This correlation between possible data-distorting events and changes in the parameters seems to suggest successful identification and incorporation of outlier effects by the stochastic coefficients model.

Figures 11 and 12 show the plots of real personal expenditures parameters and flexibilities. Unlike the results for beef and pork, there does not appear to be a strong response to the business cycle. A strong seasonal element is present in both figures. Once again, a spike is present during the 1973–74 wage price freeze period. While the mean level is slightly positive, there are periods when the parameters and flexibilities are negative, indicating that chicken may seasonally alternate between being a normal and inferior good.

CONDITIONAL FORECASTING RESULTS

For each fitted model, multi-step-ahead forecasts were obtained for the period 1980I–1983IV. This approach is in line with applied econometric practice when the costs of sequentially updating large model estimates are high. Swamy, Ken-
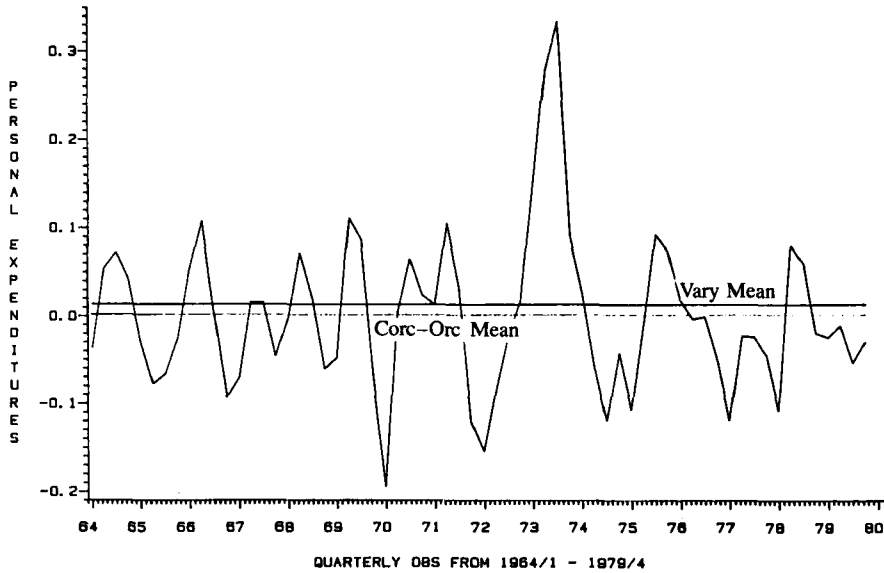
Figure 11. Plot of Varying Parameters: Chicken Price Equation. Independent Variable: Personal Expenditures. Estimation Period: 64/1–79/4.

nickell, and von zur Muehlen[20] point out that the accepted view, that one should always use all available observations, is more ambiguous than commonly known. "Without proper theoretical justification like an explicit risk minimizing motivation, a procedure that sequentially updates coefficients in a model assumed to have fixed coefficients is meaningless. Sequential updating is incorrect if some or all of the slope coefficients change over time".
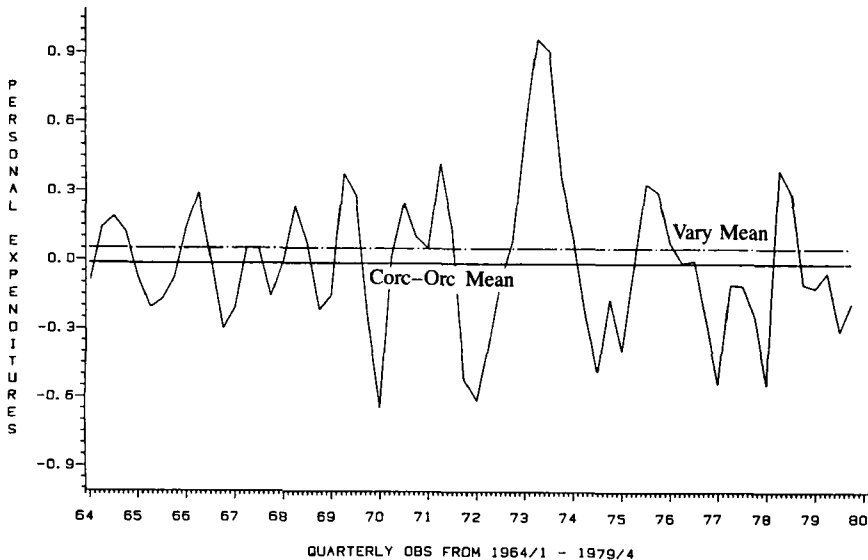

Figure 12. Plot of Flexibilities: Chicken Price Equation. Independent Variable: Personal Expenditures. Estimation Period: 64/1–79/4.

Table V.   Comparison of Varying Parameter Model to Standard Linear
Estimation Techniques, 1980I–1983IV.

Empirical Models	Root Mean Square Error		Mean Absolute Percentage Error		Turning Point Error[1]	
	Actual Value	Ratio to Varying Parameter Error	Actual Value	Ratio to Varying Parameter Error	Predicted Actual	Ratio to Varying Parameter Error
Equation 1: Beef Retail Price						
Varying Parameter	7.29	—	6.08	—	0.315	—
OLS	20.16	2.76	22.13	3.64	.750	2.38
Cochrane–Orcutt	14.00	1.92	15.32	2.52	.750	2.38
Maximum-Likelihood	12.91	1.77	14.02	2.31	.750	2.38
OLS ARIMA	18.08	2.48	19.16	3.15	.750	2.38
Equation 2: Pork Retail Price						
Varying Parameter	5.03	—	7.28	—	.318	—
OLS	8.09	1.61	12.85	1.77	.375	1.18
Cochrane–Orcutt	2.91	.58	3.87	.53	.313	.98
Maximum-Likelihood	3.09	.61	4.17	.57	.313	.98
OLS ARIMA	7.15	1.42	11.00	1.51	.375	1.18
Equation 3: Broiler Retail Price						
Varying Parameter	3.78	—	12.23	—	.375	—
OLS	6.68	1.77	24.01	1.96	.563	1.50
Cochrane–Orcutt	6.34	1.68	21.82	1.78	.500	1.33
Maximum-Likelihood	6.38	1.69	21.97	1.79	.500	1.33
OLS ARIMA	6.02	1.59	20.78	1.70	.500	1.33

NA = Not applicable.

[1]Turning point errors are calculated by subtracting the predicted from the previous actual and multiplying this value by the change in the actual value and dividing the number of negative values by the number of observations.

Using actual exogenous data throughout, we generated forecast errors for each quarter in the forecast period by subtracting the ex post actual value of retail meat prices from its ex ante predicted value. Table V compares out-of-sample forecasting results from 1980I–1983IV for the S–C model with four estimates (OLS, C–O, M–L, and OLS ARIMA) from the livestock demand equations using the same functional form—all estimated from 1964I–1979IV. We chose 1979IV as a cutoff point since the dramatic events during the last half of 1979 would provide a strong test for any empirical model to show the robustness of its forecasts. During this period, the second oil crisis had just occurred and the Federal Reserve Board had initiated its famous October change in operating procedures, switching from a Federal funds operating regime to a nonborrowed reserves operating regime. This change in operating procedures essentially amounted to targeting the money supply rather than interest rates.

All loss functions are to some extent value-laden. Therefore, we examined a

variety of forecast accuracy criteria. The mean absolute percentage error incorporates a linear loss criterion, while a mean square error incorporates a quadratic loss criterion. The stochastic coefficients model dominates all other models estimating beef and broiler price based on root mean square error (RMSE) and mean absolute percentage error (MAPE) criterion.

For pork, Cochrane–Orcutt and maximum likelihood performed better. This outcome is not necessarily an unfavorable one for the stochastic coefficients model. An examination of the coefficient of variation of the coefficients indicated that the pork equation coefficients have comparatively little variation. This result finds support from Chavas[21] and Nuankori and Miller[22] who also found evidence of parameter variation in both beef and chicken, but not pork. If there is little evidence of parameter variation in the pork equation, it is unsurprising that the maximum likelihood estimator performed better than the stochastic coefficients model.

Table V also shows turning point errors based on a "predicted minus actual" definition for all estimators. The stochastic coefficients model is equal to or superior to the C–O and M–L estimators for all three prices. These results strongly suggest that the stochastic coefficients model is generally the superior forecasting model. Based on turning point errors, results also indicate that the stochastic coefficients model performs relatively better the longer the forecasting time horizon.

CONCLUSIONS

An immediate benefit to researchers and livestock analysts from this study is the apparent forecast superiority of a stochastic coefficients model over a wide variety of criteria for quarterly beef and broiler price-dependent demand equations. Since the stochastic coefficients model can adequately represent several forms of nonstationary processes and can quickly adapt to changing economic conditions, this model quite often has an advantage in generating superior predictions over fixed slope coefficients models. The stochastic coefficients model performs exceptionally well in out-of-sample forecasting the farther out the time period.

Our results also indicate that the own quantity coefficients for the meats are relatively stable. The results would suggest the possibility of fairly stable consumer preferences for meats. Variation in the cross-commodity and intercept coefficients suggests that the information contained in the quarterly model is not complete. Other factors can and do influence consumer behavior. The stochastic coefficients estimation procedure can adjust, at least somewhat, for these problems. The empirical results from this report for all livestock equations demonstrate that the assumption of a constant relationship between the explanatory variables and endogenous variables for this specification are overly strict.

From a diagnostic point of view, the real per capita expenditures coefficients for beef and pork appear to alter their value in line with the business cycle. Macroeconomic conditions appear to have a profound effect on, or at least are correlated with, other factors which have an effect on determining red meat prices. This apparent relationship points out that a principle value of stochastic coefficients models is that they allow the data to tell more of the story. Whether or not this parameter variation can be attributed to structural change will be the subject of additional research.

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